International Journal of Engineering and Technical Research (IJETR)
ISSN: 2321-0869, Volume-2, Issue-1, January 2014

PROPERTY EVALUATION OF IGBARA-ODO CLAY FOR REFRACTORIES

B. J. Babalola, D.O. Folorunso, M.O. Bodunrin, O.P. Balogun

***Abstract*— The research work focused on evaluation of the property of Igbara-Odo clay for refractory applications. Igbara-Odo is a settlement in Ekiti State of Nigeria, located between longitudes $40^0 51'$ and $50^0 451'$ East of the Greenwich meridian and latitudes $70^0 151'$ and $80^0 51'$ north of the equator. The settlement is naturally endowed with clay deposit. The clay which was collected 1 meter below the earth surface was dried, crushed and deleterious particles were removed manually. The processed clay was then passed through a sieve shaker ranging from 1000µm, 850µm, 500µm, 300µm, 180µm, 125µm, 63µm, and pan. Property evaluation of the clay was carried out which entails refractoriness, porosity, thermal shock resistance (spalling), linear shrinkage, bulk density, and cold crushing strength. The clay without any strengthening additives was found to have refractoriness of 1330^0C, bulk density of 2.25 g/cm^3 among others properties similar to conventional refractory materials.**

***Index Terms* — Clay, Refractory, Refractoriness, Porosity, Sieve Analysis, Density**

I. Introduction

Refractory materials are inorganic materials which can withstand high temperatures (usually above 1500^0C) under the physical and chemical action of molten metal, slag and gases in the furnace. Refractory products are required for various processes in chemical, ceramic, petrochemical, oil, foundry and iron and steel industries. Refractory industry is limited in the nation despite the fact that there are abundant deposits of clay and other raw materials needed for the production of refractory products [1].

Due to large amount of natural resources deposit available in the nation, the exploration, mining and exploitation of Nigeria mineral resources have not received sufficient research attention and required technological production capacity. Clay deposit as one of the mineral deposits in Nigeria covers an estimated proven reserves of billions of tons [2]. One of such deposits in Nigeria is the Igbara-Odo town in Ekiti State of Nigeria. Major applications of this raw material in Igbara-Odo are in pottery works, plastering of building (as substandard alternative replacement for cement plastering for their buildings).

Manuscript received January 18, 2014.

B. J. Babalola, Prototype Engineering Development Institute (PEDI), Ilesa, Nigeria., National Agency for Science and Engineering, Infrastructure, Nigeria
D.O. Folorunso, Met. and Mat. Engineering Dept., Federal University of Technology., Akure, Nigeria.
M.O. Bodunrin, Met. and Mat. Engineering Dept., Federal University of Technology., Akure, Nigeria.
O.P. Balogun, Prototype Engineering Development Institute (National Agency for Science and Engineering Infrastructure), Nigeria

Refractoriness constitutes a key input in high temperature applications in many industries. The bulk of refractory requirement for these industries at the moment are imported. This situation does not favor the development of our national economy [3].

Over 80% of the total refractory materials are being consumed by the metallurgical industries for the construction and maintenance of furnaces, kilns, reactor vessels and boilers. The remaining 20% are being used in the non-metallurgical industries as cement, glass and hardware [4]. Another major application of clay is the Metallurgical industries which employ clay mixed with sand to form moulds that are used for casting operations. A lot of project research has been carried out on the conversion of clays for industrial uses. A material is refractory in nature if it has a very high melting point in addition to its physical, chemical, mechanical and thermal properties that makes it suitable for use in furnaces, kiln, reactors, and other high temperature vessels. A survey carried out on the refractory properties of six samples of Nigeria clays revealed that the clays were high in silica content and low in alumina content. They also exhibit different refractory characteristics with respect to thermal shock resistance, refractoriness, porosity, permeability, bulk density, modulus of rupture and water absorption. Investigation was carried out on the properties of termite hills as refractory material for furnace lining. In his report, he observed that the refractory properties of termite hill have a close relationship with porosity, density, dimensional change and permeability of the known refractory materials for furnace lining [5].

Due to the growing demand for refractory materials by the metallurgical Industry and others, there is need for further research in evaluation of our available raw materials.

II. Materials and Methods

The natural clay was collected as mined from 1 meter below the earth surface in Igbara-odo, Nigeria. The clay was dried, crushed and deleterious particles were eliminated by manual separation. The crushed clay was then sieved. Test pieces for various experiments were rammed into standard cylindrical sizes (30 mm in diameter, 30 mm height), dried and fired before determination of different parameters.

A. Sieve Analysis

500g of the ground clay sample were poured into prearranged sieve (of mesh size 850, 500, 300, 180, 125, 63 microns) on a vibrator. The timer on the vibrator was set at 15 minutes and the motor was switched on. At the end of the sieving period, the mass of the clay retained on each sieve was measured and percentage retained on each sieve was calculated. Table 3.1 shows the sieve analysis.

B. *Apparent Porosity*

The test samples of the clay were prepared and air dried for 24 hours. The samples were then oven dried at 110^{0}C for 24 hours. The samples were fired to a temperature of 1100^{0}C, cooled and then transferred into a 250 ml beaker in an empty vacuum dessicator. Water was then introduced into the beaker until the test pieces were completely immersed. The specimen was allowed to soak in boiled water for 30 minutes being agitated from time to time to assist in releasing trapped air bubbles. The specimen was transferred into an empty vacuum desiccator to cool. The soaked weight (W) was recorded. The specimen was then suspended in water using beaker placed on balance. This gave suspended weight (S). The apparent porosity was calculated using the equation stated below:

$$\boldsymbol{Apparent\ Porosity} = \frac{W-D}{W-S} \times 100 \text{ ------------- (i)}$$

Where W = Soaked Weight
D = Dried Weight
S = Suspended Weight

C. *Bulk Density*

The clay samples were air-dried for 24 hours and then oven dried at 110^{0}C, cooled in a dessiccator and weighed to the accuracy of 0.001 g (dried weight) after which the sample were heated in a boiling water contained in a beaker for 30 minutes so as to release the trapped air. The samples were cooled and soaked weights (W) were taken. The bulk density was calculated by the equation below:

$$\boldsymbol{Bulk\ Density} = \left(\frac{Dpw}{W-S}\right) g/cm^3 \text{ ------- (ii)}$$

D. *Cold Crushing Strength*

Cylindrical test pieces were prepared to a standard size (30 mm in diameter, 30 mm in height). The test pieces were fired in a furnace at 1,100^{0}C and the temperature maintained for 6 hours. The specimen was placed on a compressive tester and load was applied axially by turning the hand wheel at a uniform rate till failure occurs. The manometer readings were recorded. Cold crushing strength (CCS) was calculated from the equation stated below;

$$CCS = \frac{\text{Maximum Load (KN)}}{\text{Cross Sectional Area (m2)}} \text{ ---------- (iii)}$$

E. *Refractoriness Test*

Test pieces measuring 30 mm height by 30 mm diameter were prepared, dried and fired to temperature of 900^{0}C in a muffle furnace maintained for 10 minutes. The temperature is then raised to above 1000^{0}C at a rate of 10^{0}C per minute. The melting point of the refractory is determined indirectly through comparison with so-called Seger Cones (PCE-Pyrometric Cone Equivalent).

F. *Thermal Shock Resistance*

The clay samples were prepared and inserted in a furnace which has been maintained at temperature of 900 ^{0}C. The temperature was maintained for 10 minutes. The samples were removed with a pair of tongs from the furnace one after the other and then cooled for 10 minutes on firebrick. The samples were returned into the furnace for further heating. This process was continued until the test pieces were readily pulled apart in the hands. The number of cycles of heating and cooling possibly attained by the clay was recorded.

G. *Chemical Analysis*

Atomic Absorption Spectrophotometer (AAS) was used in viewing the chemical composition of the clay. The percentage compositions of the clay are given in Table 3.3. It is a method of classifying materials. It shows whether a brick/clay is a typical silica, magnesite, dolomite, chrome, or fireclay product, or, say, a composite brick (such as chrome-magnesite).

III. RESULTS

If you are using *Word*, use either the Microsoft Equation Editor or the *MathType* add-on (http://www.mathtype.com) for equations in your paper (Insert | Object | Create New | Microsoft Equation *or* MathType Equation). "Float over text" should *not* be selected.

Table 1 Sieve Analysis of Igbara – Odo Clay

MESH SIZE	MASS RETAINED(G)	% RETAINED	% PASSING	MULTIPLIER	PRODUCT
1MM	22.44	4.47	95.51	5	5
850MICRON	40.10	8.02	87.49	7	5.95
500MICRON	98.57	19.72	67.78	20	10
300MICRON	103.6	20.72	47.06	35	10.5
180MICRON	130.9	26.18	20.88	50	9
125MICRON	81.22	16.24	4.64	70	8.75
63MICRON	17.78	3.56	1.08	145	9.135
PAN	5.3	1.06	-	-	-

Table 2 showing Properties of Igbara – Odo clay

S/N	PROPERTIES	X1	X2	X3	AVERAGE VALUE	*FIRECLAY
1	THERMAL SHOCK RESISTANCE	+21	+23	+19	+21	20-30
2	APPARENT POROSITY	36.68	35.30	37.10	36.36	20-30
3	BULK DENSITY (G/CM^3)	2.10	2.35	2.30	2.25	2.29-2.36
4	REFRACT'(^{0}C)	1300	1360	1330	1330	1500-1700
5	FLS (%)	8.8	9.0	8.6	8.8	7-10
6	CCS	236.9	253.84	248.14	246.32	352-564

*Fireclay-Sourced: Chester (1983)
REFRACT' (^{0}C) – REFRACTORINESS
FLS – FIRED LINEAR SHRINKAGE (%)
CCS – COLD CRUSHING STRENGHT (KG/CM^2)

A. *Sieve Analysis*

The clay sample was mostly retained at the 180µm sieve showing good proportion of the clay being refined as shown in Table 3.1 above.

B. *Chemical Analysis*

Table 3 shows the chemical composition of the clay sample. From its chemical composition, the clay fall under Aluminum-silicate type of clay because of its high value of aluminum-oxide and silicon oxide which are highest among other chemical composition of the clay.

Table 3 showing chemical analysis of Igbara-Odo clay

COMPOSITION	PERCENTAGE (%)
SIO_2	54.6
AL_2O_3	26.10
FE_2O_3	1.50
TIO_2	1.87
CAO	0.15
MGO	0.20
K_2O	1.06
NA_2O	0.04
LOI	10.70

C. *Thermal Shock Resistance*

The test showed that Igbara – Odo clay resist spalling up to 20 cycles which is brought about as a result of uniform heating and cooling as shown in Table 3.2.

The thermal shock resistance value is within the acceptable values of 20-30 cycles as reported by [6].

D. *Refractoriness*

The average refractoriness of Igbara – Odo clay is given as $1{,}330^0$C in Table 3.2. This is low compared to the values quoted for fireclay which is within $1{,}500^0$C – $1{,}700^0$C [5]. With this quotation, it implies that Igbara – Odo clay is not suitable for application in furnaces carrying out operations and melting operations at elevated temperature beyond $1{,}300^0$C. The clay possesses low refractoriness due to its high apparent porosity value and the presence of particles such as Fe_2O_3, TiO_2, K_2O, Na_2O and others.

E. *Porosity*

There are a number of factors that are known to affect the porosity of refractory raw materials, especially fireclays. Some of the factors include the clay composition, size and shapes of particles, ramming pressure, and the reaction occurring on firing. The porosity measures the ease with which liquid and gas slip through the refractory material [7]. Porosity affects the strength of refractory material as well as its insulating capabilities. The average apparent porosity was determined to be 36.36% as shown in Table 3.2, and it was found to out of range as quoted by [6] to be 20% - 30% for fire clay or with most refractory bricks. The high apparent porosity value will create room for penetration molten metal, molten slag, and flue gases and this will corrode the refractory bricks faster if applied in melting furnaces.

F. *Bulk Density*

The bulk density was determined, and was found to obtain an average value of $2.25g/cm^3$ as shown in Table 3.2. The average bulk density of Igbara- Odo clay falls within the range quoted for high alumina refractoriness, 2.2 – 2.8 g/cm3, as reported by [8]

G. *Linear Shrinkage*

The average value of the fired linear shrinkage of Igbara – Odo clay is 8.8% as shown in Table 3.2, which is within the allowable range, 7 – 10% for fireclay as given by [6]. This firing shrinkage always gives an indication of the firing efficiency.

H. *Cold Crushing Strength*

The average value obtained for Igbara – Odo clay is 246.32Kg/cm2 which is low compared to standard values quoted by [6] as within range of 352Kg/cm2-564Kg/cm2. Cold crushing strength of refractory materials correlates closely with abrasion and loading resistance, an important property to be considered in furnace lining. It implicates that it cannot withstand resistance to damages of edges and corners of the refractory clay due to movement of load. This is an indication of low mechanical strength.

IV. CONCLUSION

This research work determines the property evaluation of igbara-odo clay for refractories. From the overall experimental analysis carried out, it was observed that some of the properties of the clay have reasonable values compared to the imported refractory material (Fireclay).

The properties of the clay such as thermal shock resistance, bulk density, fired linear shrinkage as shown in Table 2 were found to exhibit similar features with fireclay as reported by [6].

The clay possesses a high apparent porosity value as shown in Table 2, a low duty refractoriness value which indicates high insulating capability of the clay and low thermal conductivity.

From failure analysis concept, the value 246.32 kg/cm^2 exhibited by the material as against (352-564) kg/cm^2 reported by [6] obtained for cold crushing strength cannot be sustained at elevated temperature. This implies that the load which the material can withstand at elevated temperature drops before reaching its refractoriness value.

Chemical analysis conducted for the clay indicated high silica content which is higher than 40% as reflected in Table 2, and therefore classified as acidic refractory.

A significant discovery is that the clay can be used as insulating refractory material in furnace lining as it cannot be applicable in inner core (hot zone) lining of the furnace.

It can find extensive use in lining of soaking pits and reheating furnaces, safety lining of steel ladles and kilns in cement industry due to its insulating properties and thermal shock resistance capability.

REFERENCES

[1] Abdullahi M. Y., and Samaila U., 2007, "Characterization of Some Nigerian Clays as Refractory Materials for Furnace Lining". Continental Journal of Engineering Sciences2: Wilolud Online Journals, pp30-35.

[2] Abolarin,M.S., Olugboji, O.A.; and Ugwuoke I.C..(2004); *"Experimental Investigation on Local Refractory Materials for Furnace Construction"*. 5th Annual Engineering Conference, Federal University of Technology, Minna, Niger. pp82-85

[3] Daniel-Mkpume C.C., Offor P.O., and Obiorah S.O., 2011, *" Blending of Nsu and Ibeku Clays: A Solution Towards the Replacement of GP107-3 Refractory Brick in The Metallurgical Industry"*. Nigerian Journal of Technology, Vol. 30, No. 2.

[4] Aderibigbe, A., and Chukwuogo, B. (1984); "*Potentials of some Nigerian clay deposits as refractory material for steel industry"*. Nigerian Society of Engineers., pp 132-8.

[5] Akinbode, F.O. (1996); *"An investigation on the properties of termite hill refractory material for furnace lining"*, India Found. J.

[6] Chester, J.H. (1983); ―*Refractoriness: Production and Properties*‖. The Metal Society, London, UK, Pp. 492-510.

[7] Omotoyinbo J.A., and Oluwole O.O., 2008, *"Working Properties of Some Selected Refractory Clay Deposits in South Western Nigeria"*. Journal of Minerals and Materials Characterization and Engineering. USA. Vol 7, No. 3, pp233-245

[8] Omowumi, O.J.(2001): *"Characterization of some Nigeria Clays as refractory materials for furnace lining"* Nigeria Journal of Engineering Management, No 3, Volume 2, Besade Pulishing Press, Ondo.

B. J. Babalola, Prototype Engineering Development Institute (PEDI), Ilesa, Nigeria., National Agency for Science and Engineering, Infrastructure, Nigeria

D.O. Folorunso, Met. and Mat. Engineering Dept., Federal University of Technology., Akure, Nigeria.

M.O. Bodunrin, Met. and Mat. Engineering Dept., Federal University of Technology., Akure, Nigeria.

O.P. Balogun, Prototype Engineering Development Institute (National Agency for Science and Engineering Infrastructure), Nigeria